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Eek Lake Sockeye Salmon (*Oncorhynchus nerka*) Stock Assessment Project 2003 Annual Report

by

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October 2005

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL
Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 05-53

EEK LAKE SOCKEYE SALMON (*ONCHORHYNCHUS NERKA*) STOCK ASSESSMENT PROJECT 2003 FINAL REPORT

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The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

The village of Hydaburg, founded in 1911, was located in close proximity to sockeye salmon (*Oncorhynchus nerka*) streams in Hetta Inlet, especially the Hetta Lake system. Subsistence fishers from Hydaburg, however, frequently target sockeye salmon in Eek Inlet when returns to the Hetta Lake system are low. Eek Inlet is also closer to Hydaburg than Hetta Cove, making travel cheaper and easier especially in rough weather. Residents in Hydaburg have recently become concerned about apparent declines in sockeye harvests in both the Hetta and Eek subsistence fisheries. In 2003, the Hydaburg Cooperative Association, in cooperation with the Alaska Department of Fish and Game (ADF&G), initiated a sockeye research project in Eek Lake. We interviewed subsistence fishers to get an accurate estimate of the harvest, estimated sockeye spawning population using mark recapture methods, and described zooplankton population sizes and the physical characteristics of the lake to evaluate the productivity of Eek Lake. In 2003, subsistence fishers from Hydaburg harvested about 1,100 sockeye salmon in the Eek Inlet subsistence fishery but only reported harvesting 153 fish on the state subsistence permits. We estimated about 1,200 sockeye salmon spawned into Eek Lake in 2003. Our first look at the freshwater environment in Eek Lake showed a shallow (4 m) euphotic zone depth, extensive heating in the summer months, and a very simple zooplankton community dominated by the copepod *Cyclops*. The response of the zooplankton populations to the number of off-spring produced by the spawning population will, in part, assist biologist in determining the level of escapement needed to sustain this population while providing subsistence opportunities. We recommend continued monitoring of sockeye subsistence harvest and escapement in this system, as well as additional assessment of the freshwater habitat.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Eek Lake, Hydaburg, Prince of Wales Island, escapement, mark-recapture, harvest census, zooplankton.

INTRODUCTION

The Haida people migrated to Prince of Wales Island from the Queen Charlotte Islands in the late 17th century (Langdon 1977). They established for main villages: Klinkwan, Howkan, Kaigani, and Sukkwan in the southwest region of the island. Archeological evidence, including pictographs along Hetta Inlet, supports the Haida people's claim to traditional areas including Cordova Bay, Dall, Sukkwan, and Long Islands. In 1911, government and church officials pressured the Haida people to consolidate these villages into one central location to take advantage of governmental services such as a centralized school (Betts et al. 1997). The sockeye salmon resources in Hetta and Eek Inlets were, in part, the reason that Hydaburg was established approximately 15 km due west of Hetta Inlet.

In modern times, Hydaburg residents still depend heavily upon salmon resources near the village. In a recent survey, 100% of Hydaburg households reported using subsistence fisheries resources, with 82% specifically reporting use of sockeye salmon. The near shore areas and creeks around Hydaburg, Sukkwan Island, and Hetta Inlets are favored for subsistence fishing (Betts et al. 1997). Because of rising fuel costs, the shorter distances from Hydaburg to Eek Inlet (12 km) and Hetta Inlet (17 km) make these two traditional harvest areas more economical choices for subsistence fishing than Kasook (27 km) and Hunter Bay (50 km; Figure 1). However, the intensity of the subsistence harvest in any one system depends on the strength of the returns in any given year (Tony Christensen, Hydaburg Cooperative Association (HCA) Hetta Lake Project Manager, personal communication 2004).

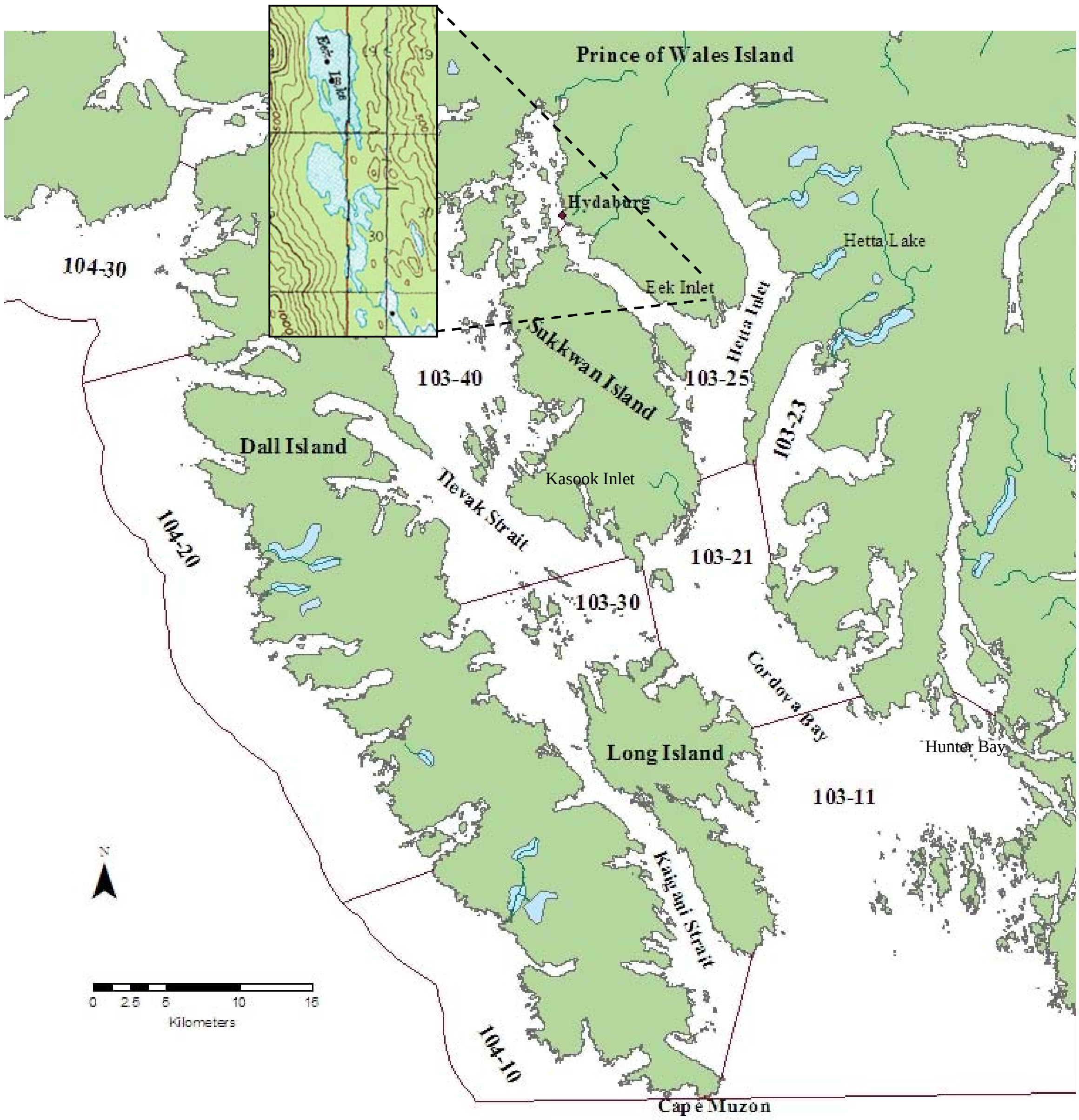


Figure 1. –The geographic location of Eek Lake (inset), draining into Eek Inlet on southeast Prince of Wales Island, in relation to the village of Hydaburg, Hetta Lake, Kasook Inlet, and Hunter Bay. Commercial fishing sub-districts along southwestern Prince of Wales Island are also shown.

Commercial exploitation of Eek Lake sockeye salmon began in the late 1800s. Moser (1898) found evidence of a barricade at the outlet of Eek Lake, but it was unclear how long it had been in use. Sockeye salmon were sent to the cannery at Klawock and a saltery at Hunter Bay prior to the establishment of the cannery at Hunter Bay. This marked the beginning of exploitation of sockeye salmon runs in many localities in the Cordova Bay area. According to Moser (1898), the Hunter Bay cannery operation harvested about 9,000 sockeye salmon from Eek Inlet in 1896 and 1897 (Table 1). The Klawock cannery also harvested sockeye salmon in Eek Inlet during the same time period, but no harvest numbers were reported. Four additional salteries opened in the next three years at Nutkwa Inlet, Sukkwan, Kasook, and Copper Harbor, but none of these operated past 1907 (Rich and Ball 1933).

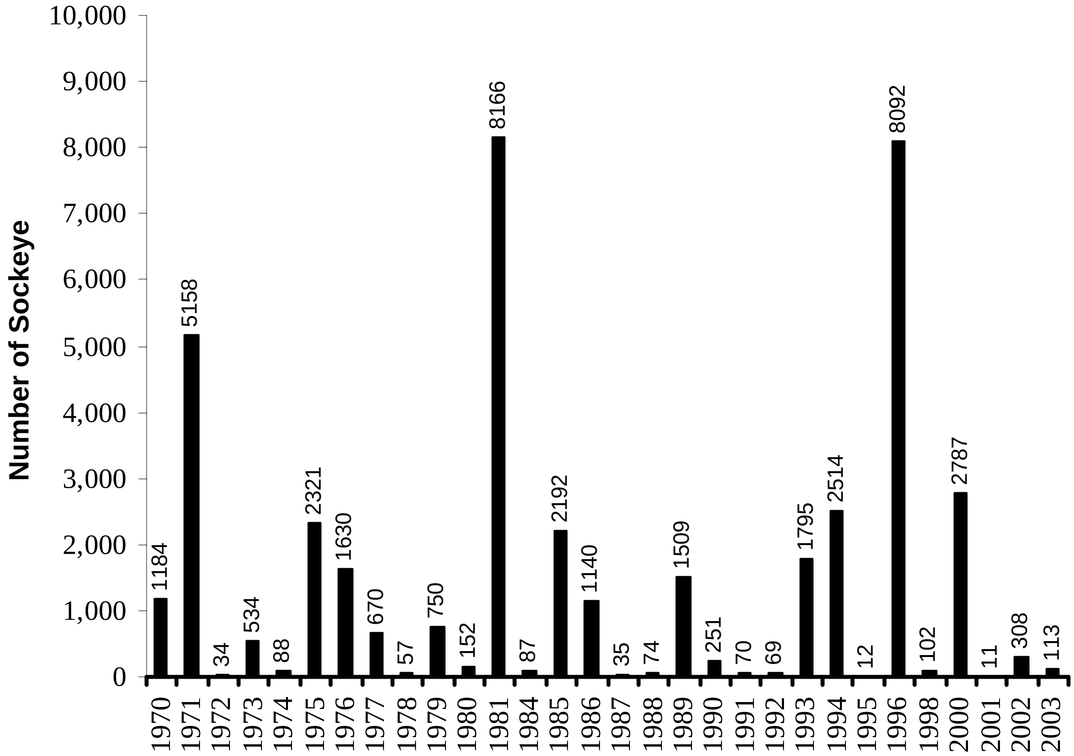
Table 1.–Commercial harvest of sockeye salmon from Eek Inlet and Eek Point.

Year	Eek Inlet	Eek Point
1896	8,688	-
1897	9,213	-
-	-	-
1908	4,413	-
1909	4,752	-
1910	6,684	-
1911	3,917	-
1912	6,917	-
1913	-	-
1914	903	-
1915	70	-
1916	2,656	1,068
1917	-	-
1918	2,009	2,550
1919	3,000	69
-	-	-
1922	-	2,703
1923	2	608
1924	-	994
1925	-	-
1926	-	87
1927	-	641

Source: Rich and Ball 1933.

Commercial fishing activity in the Cordova Bay area intensified after the Rose Inlet cannery, located on the east coast of Dall Island north of Kaigani Strait, opened in 1912. Fish traps replaced seines and gillnets as the most commonly used gear in this area. Regulation of commercial fishing began during this time period. Streams and the areas immediately around the mouths of streams were progressively closed to all commercial fishing between 1918 and 1921. Starting in 1924, closures during certain periods of the season were implemented. In 1925 Hetta Inlet was closed north of Eek Point, which effectively ended commercial fishing in Eek Inlet and other highly productive bays and inlets in the vicinity (Rich and Ball 1933).

In more recent times, Eek Lake sockeye salmon have likely contributed to mixed-stock commercial purse seine fisheries in Hetta Inlet and Cordova Bay. The commercial harvest of sockeye salmon in Hetta Inlet (sub-district 103-25) has fluctuated during the past 30 years, with one exceptionally high annual harvest in 1965 of 23,000 sockeye (Figure 2). Commercial fishery openings in Hetta Inlet have traditionally opened in mid-August (Steve Heinl ADF&G, personal communication 2004). Most of the subsistence harvest takes place prior to mid-August. However, we do not know the extent to which Eek Lake sockeye salmon contribute to the overall commercial harvest in Hetta Inlet.



Source: ADF&G Division of Commercial Fisheries database 2004

Figure 2.–Commercial harvest of sockeye salmon for years 1970–2003 in sub-district 103-25.

We had no previous estimates of salmon escapements into Eek Lake, nor had the freshwater environment and juvenile sockeye life stages been studied in this system prior to this project. The 2003 study included a subsistence harvest estimate, a mark-recapture estimate of adult sockeye escapement, and estimates of the zooplankton population and physical characteristics of the lake. This assessment of sockeye production in Eek Lake, along with continued monitoring in the future, will provide fisheries managers with information to help sustain both harvest opportunities and escapement of sockeye salmon. In this annual report we summarize information collected in 2003, the first year of study for Eek Lake.

OBJECTIVES

1. Estimate escapement of sockeye salmon adults into Eek Lake using a mark-recapture method, so that the estimated coefficient of variation is less than 15%.
2. Describe the age, length, and sex composition of the sockeye salmon in the Eek Lake spawning population.
3. Census the subsistence harvest of sockeye salmon at Eek Inlet.
4. Collect baseline data on productivity of Eek Lake using established ADF&G limnological sampling procedures, which include physical characteristics of the lake and zooplankton density and biomass estimates.

STUDY SITE

Eek Lake (ADF&G stream #103-25-009) is located on the southern side of Prince of Wales Island approximately 12 kilometers from Hydaburg (Figure 1). Two small lakes connected by a short 120 m high gradient riffle are together referred to as Eek Lake. The elevation of the upper lake is 30 meters. This study was conducted in the upper portion of the lake. The inlet creek is approximately 2.2 km in length. The outlet, Eek Creek, empties into Eek Inlet, approximately 200 m from the lake. Typical of north temperate coastal lakes in Southeast Alaska, Eek Lake is dimictic, developing thermal stratification in the summer and becoming isothermic in the fall and spring. The total lake surface area is 79 hectares. The depth at sampling station A is 13.5 m and the depth at sampling station B is 12.3 m (Figure 3); Additional bathymetric or limnological information is not available for Eek Lake. The average annual rainfall in the area is approximately 400 cm. Native fish species include sockeye (*Oncorhynchus nerka*), coho (*O. kisutch*), pink (*O. gorbusha*), and chum (*O. keta*) salmon, cutthroat (*O. clarkii clarkii*) and steelhead (*O. mykiss*) trout, Dolly Varden char (*Salvelinus malma*), threespine stickleback (*Gasterosteus aculeatus*), and cottids (*Cottus* sp.).

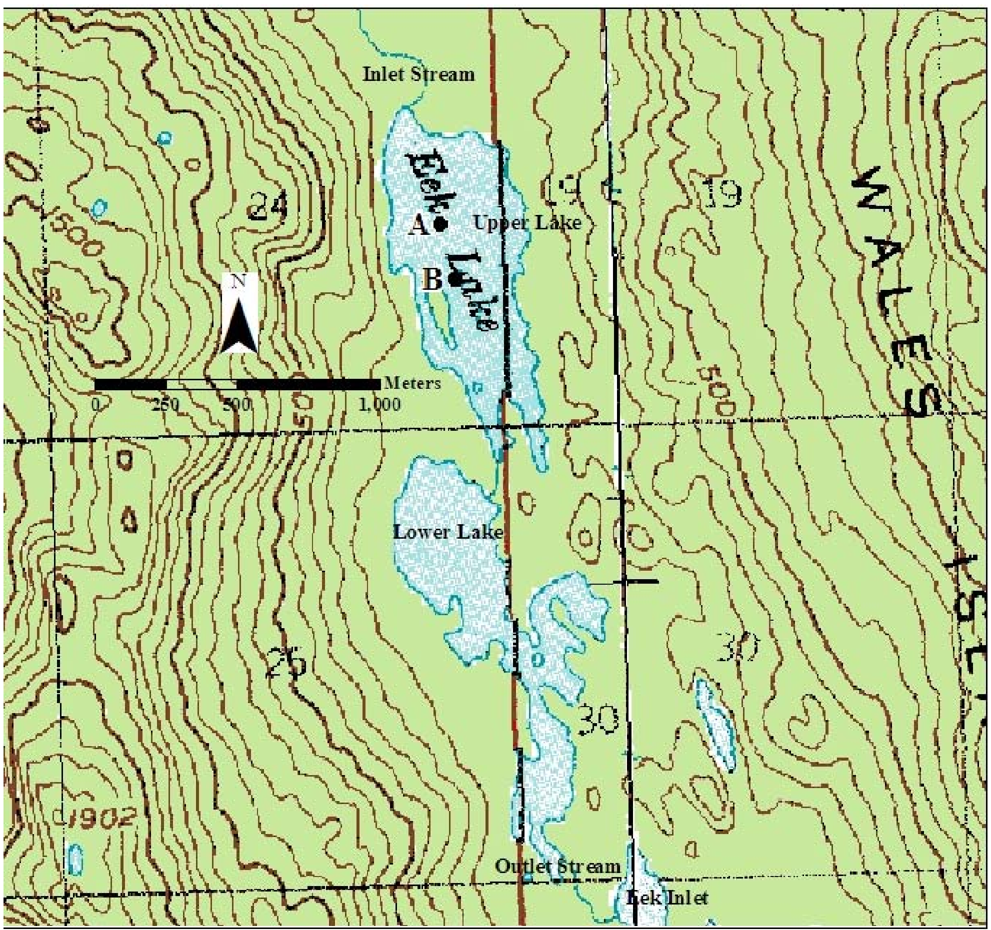


Figure 3.–Topographic map showing the upper and lower parts of Eek Lake, inlet stream, outlet stream, permanent limnology sampling stations (A and B), and the head of Eek Inlet.

METHODS

SOCKEYE SALMON ESCAPEMENT ESTIMATES

We used mark-recapture methods to estimate the sockeye escapement in the major spawning stream in Eek Lake in 2003. The study area was defined as the first kilometer of the inlet stream and approximately 10m on each side of its mouth. Because the capture probability most likely varied over time, a stratified, two-sample mark-recapture procedure was used to estimate escapement (Seber 1982; Arnason et al. 1995). In a temporally stratified mark-recapture experiment, all individuals released during each of a series of non-overlapping periods (strata) bear the same distinct mark, so that each recaptured fish can be identified by the period during which it was released and period during which it was recaptured. Three assumptions are required to justify the estimate: 1) Closure; no fish enter or leave between the two sample times, 2) No mark loss; fish retain their marks and are correctly identified as marked or unmarked, 3) Equal catchability; all fish in a given recapture stratum, whether marked or unmarked, have the same probability of being sampled.

The field crew conducted five mark-recapture sampling events in Eek Lake, approximately every two weeks over the entire spawning period. Prior to each mark-recapture event, the crew made visual counts of sockeye spawners in the inlet stream and around the mouth of the stream. Each crewmember recorded his counts separately. The crew checked other areas of the Eek Lake system (the upper lake, the lower lake, and the stream joining them) for sockeye spawners on each sampling trip, but never observed any spawners in these other areas. The crew used a beach seine, 40 m long and 4 m deep, deployed with the aid of a small skiff and outboard motor, to capture sockeye salmon at the mouth of the inlet stream.

The mark-recpature study was comprised of a marking phase and a recovery phase. During the marking phase, all sockeye salmon caught were first inspected for previous marks. Fish with previous marks were disregarded during the marking phase. Fish without previous marks were marked with a unique operclular punch pattern identifying the sampling event, and released with a minimum of stress; the number of fish released with marks was recorded for each sampling event. The recovery phase of the sampling was conducted in the inlet stream, beginning with the second sampling event. The crew used dip nets to capture live fish; both live and dead fish were counted and examined for marks and given a second mark (opercle punch) to prevent duplicate sampling at a later time. They recorded the total number of fish observed for marks and the total number of marked fish by each opercular punch pattern.

Data Analysis

Darroch maximum-likelihood and least-squares, Schaefer population, and “pooled Petersen” estimates were calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995; for details, refer to www.cs.umanitoba.ca/~popan/). Because an estimate of escapement was the only estimate required for our project, SPAS had the advantage of allowing us to pool together some or all of the capture or recapture strata to get a more precise estimate of escapement, possibly at the expense of some bias. If a simple Petersen method is applied to stratified data that have been pooled, the resulting estimate is called the pooled Petersen estimate (Seber 1982). However, the Petersen estimate can be badly biased when the assumptions of equal probability of capture are violated. Briefly stated, the three assumptions of equal probability of capture are: 1) all fish have an equal probability of capture in the first event, 2) all fish have an equal probability of capture in the second event, and 3) fish mix completely between the first and second event. SPAS provides two types of chi-square tests to test whether the assumptions of equal probability of capture are likely to have been met. The software developers included the test labeled Complete Mixing to test the assumption that there is no difference in probability of movement for fish marked in any first-event stratum to any second-event stratum. This test is equivalent to determining if there is a difference in capture probability for fish in the second event. The software developers included the test labeled Equal Proportions to test the assumption that there is no difference in probability of capture for fish marked in the first event. If the test statistic from either of these tests was not significant ($p > 0.05$), we concluded that we met the assumptions of complete mixing and equal capture probability. Even if one of the test statistics was significant ($p \leq 0.05$), we considered this to be insufficient evidence of a problem with the pooled Petersen estimate, and considered that partial or complete pooling could still be valid (Arnason et al. 1995). Other criteria were examined, including seeing if pooling produced big changes in the estimate of escapement. If pooling led to a small change, we concluded that it was probably safe to pool; however, if pooling led a big change in the estimate, the pooled Petersen estimate may be badly biased. Using the chi-square tests in SPAS as guidelines, we attempted to pool as many strata as possible to increase precision. If both tests were significant ($p \leq 0.05$), however, we used the less precise Darroch or stratified population estimate.

When use of the pooled Petersen method was warranted, we used the following method to estimate the 95% confidence interval for the escapement estimate, rather than the method provided in the SPAS software. We let K denote the number of fish marked in a random sample of a population of size N. We let C denote the number of fish examined for marks at a later time, and let R denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, $\hat{N}$, is given by $\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1$.

In this equation, R is a random variable, and it can be assumed to follow a Poisson, binomial, hypergeometric, or normal distribution, depending on the circumstances of the sampling. When R is large compared with the size of the second sample, C, its distribution can be assumed to be approximately normal (a practical check is to ensure R is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population such that $\hat{p} = \frac{R}{C}$. We used approximate confidence interval bounds for $\hat{p}$ based on the assumption that R follows some sampling distribution. We defined the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, N^*, were found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by K. That is, the confidence bounds for the Petersen estimate are given by ($K \cdot 1/a_{0.975}$, $K \cdot 1/a_{0.025}$). If $\hat{p} \geq 0.1$, and the size of the second sample C is at least the minimum given in Table 2, a 95% confidence interval for $\hat{p}$ is given by $\hat{p} \pm \left[1.96\sqrt{\left(1 - \frac{C}{\hat{N}}\right) * \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right]$, (Seber 1982, eq. 3.4).

Table 2.–Sample size criteria for using Seber's (1982) eq. 3.4 to find 95% confidence interval for a proportion. For given proportion, minimum sizes for the second sample are indicated.

Proportion or 1 minus the proportion	0.5	0.4	0.3	0.2	0.1
Minimum sample size	30	50	80	200	600

Seber's (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for $\hat{p}$ were found from Table 41 in Pearson and Hartley (1966).

SOCKEYE ESCAPEMENT AGE AND LENGTH DISTRIBUTION

We collected scales and recorded length and sex from adult sockeye salmon during the mark-recapture study, to describe the age and size structure of the spawning population. The goal was to collect 600 samples through the spawning season (Thompson 1992). Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Personnel in the ADF&G salmon aging laboratory in Douglas, Alaska, aged all scale samples. Age classes were designated following the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 1 year freshwater and 3 years saltwater). Brood year tables were compiled by sex and brood year. The length of each fish was measured from mid eye to tail fork to the nearest millimeter (mm).

The proportion of each age-sex group k and associated standard errors of the proportions were calculated by the standard binomial formula: $\hat{p}_k = \dfrac{n_k}{n}$, and $SE(\hat{p}_k) = \sqrt{\dfrac{\hat{p}_k(1-\hat{p}_k)}{n-1}}$,

where n_k is the number of samples in age-sex group k, n is the total number of samples aged, and N is the estimated escapement (Thompson 1992, p. 35–36).

The mean length and associated standard error for age-sex group k were calculated by standard normal methods: $\bar{y}_k = \dfrac{1}{n_k}\sum_{i=1}^{n_k} y_{ki}$, and $SE(\bar{y}_k) = \sqrt{\dfrac{1}{n_k^{\,2}}} \cdot \sqrt{\left(\dfrac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2}$ (Thompson 1992, p. 42–43).

SUBSISTENCE HARVEST ESTIMATE

Subsistence fishers in Hydaburg were interviewed to determine fishing time, location, duration, gear, and total harvest by salmon species, for each boat or group of participants. Because of multiple exits between the harbor and the fishery, we were not able to follow a standard sampling survey to select participants for interviews (see Bernard et al. 1998 for details). However, because this is a small close-knit community, the crew was able to independently interview all participants—making this a harvest census. The total harvest is simply the sum of harvests by all participants, with no sampling error.

The crew conducted interviews every day that the fishery was open (1 June to 31 August), and interviewed every party that fished. If they were unable to interview participants in the fishery or at the boat harbor, they contacted participants at their homes. The crew was confident they interviewed all participants in the fishery.

LIMNOLOGY SAMPLING

Limnology sampling was scheduled at six-week intervals from mid-May through October, for a total of five sampling dates using the ADF&G standard sampling protocol (Koenings et al. 1987). Two permanent limnology stations were installed in the upper lake. The physical data was only taken at Station A (N55°10.694', W132°40.578' ;) and a zooplankton; B-N55°10.587', W132°40.536'). Physical data were taken only at Station A and zooplankton samples were collected from both stations on each sampling date.

Light Temperature, and Dissolved Oxygen Profiles

The amount of light penetrating the water column drives the metabolic processes of the primary producers who convert sunlight into energy (photosynthesis). The volume of the lake that is capable of photosynthesis is called the euphotic zone region of the lake. To estimate this volume, we measure the light intensity from just below the surface of the water to the depth in which 1% of the subsurface light penetrates the water column. Light measurements were recorded in foot-candles every 0.5 m, using a Protomatic light meter. The vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was calculated from the equation, EZD = 4.6205/ K_d (Kirk 1994). The product of the euphotic zone depth and the surface area provides an estimate of the volume of the lake in which photosynthetic activity is possible.

The heat budget of a lake influences the chemical reactions, nutrient turnover rate and ultimately productivity. Dissolved oxygen is not only necessary for aerobic respiration, it affects most of the biochemical reactions in the aquatic environment. Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe which was calibrated each sampling trip with a 60 ml Winkler field titration (Koenings et al. 1987). Temperature and DO measurements were made at 1 m intervals for the first 10 m or to the lower boundary of the thermocline (defined as the depth at which the change in temperature decreases to less than 1 per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 44 m). Temperature was measured in degrees centigrade. The absolute DO (mg L^{-1}) and temperature (ºC) values were used to calculate the percent dissolved oxygen by hand using a nomograph for each depth and sample date (Koenings et al. 1987).

Secondary Production

Zooplankton samples were collected at two stations on Eek Lake using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a depth of 9 m at both stations at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G, Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Cladocerans and copepods were identified using the taxonomic keys of Brooks (1957), Wilson (1959), and Yeatman (1959). Zooplankton were enumerated from three separate 1 ml subsamples taken with a Hensen-Stemple pipette and placed in a 1 ml Sedgewich-Rafter counting chamber. Zooplankton body length was measured to the nearest 0.01

mm from at least 10 organisms of each species along a transect in each of the 1 ml subsamples using a calibrated ocular micrometer. Zooplankton biomass was estimated using species-specific dry weight versus zooplankter length regression equations (Koenings et al. 1987). The seasonal mean density and body size was used to calculate the seasonal zooplankton biomass (ZB) for each species. Marco-zooplankters were further separated by sexual maturity where ovigorous (egg bearing) zooplankters were also identified.

RESULTS

SOCKEYE SALMON ESCAPEMENT ESTIMATES

We marked and released a total of 524 sockeye salmon at the mouth of the inlet stream during two mark-release events in the early part of the spawning period (Table 3). We were unable to complete the third planned mark-release event due to high water. During the recovery phase, we examined a total of 255 sockeye salmon in Eek Creek, and we recaptured a total of 112 marks during two mark-recovery events in the later part of the spawning period. The first two attempted mark-recovery events were unsuccessful because high water made it impossible to sample fish with dip nets in the stream.

Table 3.–Summary of mark-recapture sampling of sockeye salmon at Eek Inlet Creek, 2003.

Event date	Number marked and released	Number marks recovered, by mark date		Total number sampled for marks
		26–29 Aug	9–10 Sept	
26–29 Aug	367	-	-	-
9–10 Sept [a]	157	na	-	na [a]
19–20 Sept [b]	na [b]	-	-	na [b]
26–27 Sept	-	62	20	205
10-Oct	-	12	10	50
Total marked and released:	524			
Total recoveries, by mark date:		82	30	
Total number sampled for marks:				255

[a] Unable to conduct a recapture event in stream due to high water.
[b] Unable to mark or recapture any fish due to high water.

We estimated a population of 1,230 sockeye spawners in Eek Creek, with a 95% confidence interval of 1,090–1,430 (CV = 7%), using the pooled Petersen estimator. Both chi-square tests for consistency included in the SPAS software package were non-significant (p >0.05), indicating there were no detectable violations of the assumptions of complete mixing, equal probability of capture in the second event, or equal probability of capture for fish marked in the first event. Since both of the consistency tests passed (i.e. were non-significant), we decided to use the pooled Petersen estimate to increase precision, possibly at the expense of some bias.

From the sampling period between 26 August and 9 October, the highest count from 4 visual surveys performed was 348 sockeye salmon on 26 August (Table 4). Since the highest count occurred on the first survey date, it is unknown whether this represents a peak count. No sockeye spawners were observed in any other part of the Eek Lake system, so we assumed the study area counts represented all of the sockeye spawners present in the lake. However, it is still possible there may have been spawners in locations that were not visible to the observers.

Table 4.–Escapement survey estimates of adult sockeye by date for Eek Creek, 2003.

	Sockeye Counts[a]			
Date	**Stream Mouth**	**In Stream (Live)**	**In Stream (Dead)**	**Total**
26-Aug	290	58	0	348
9-Sept[b]	90	na[b]	na[b]	na[b]
26-Sept	0	78	128	206
9-Oct	0	4	78	82

[a] All survey estimates are averaged from two crew members counts.

[b] Unable to do a full survey on 9 September trip due to high water.

Sockeye Escapement Age and Length Distribution

A total of 492 adult sockeye salmon were sampled for age, sex, and length in 2003 (Table 5). Typical in most sockeye system in Southeast Alaska, the dominant age class was age 1.3 (68.3%) followed by age 1.2 (23.2%). Females outnumbered males within the dominant age class and in the sample as a whole, but males were more numerous in the age-1.2 class. The mean fork length was 577 mm for age-1.3 fish, and 507 mm for age-1.2 fish (Table 6).

Table 5.–Age composition of sockeye salmon by brood year age and percent sample size Eek Lake.

Brood year	**2000**	**1999**	**1999**	**1998**	**1998**	**1997**	
Age	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Males							
Number	9	75	13	89	4	3	193
Percent	1.8	15.3	2.6	18.1	0.8	0.6	39.3
Std. Error	0.6	1.6	0.7	1.7	0.4	0.3	2.2
Females							
Number		39		246	5	8	298
Percent		7.9		50.1	1.0	1.6	60.7
Std. Error		1.2		2.2	0.4	0.6	2.2
All Fish							
Number	9	114	13	336	9	11	492
Percent	1.8	23.2	2.6	68.3	1.8	2.2	100%
Std. Error	0.6	1.9	0.7	2.1	0.6	0.7	

Table 6.– Mean fork length (mm) of sockeye salmon in Eek Lake escapement by sex, brood year and age class.

Brood Year	2000	1999	1999	1998	1998	1997	
Age	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Males							
Av. Length (mm)	359	504	380	589	494	584	529
Std Error	3.8	4.4	5.6	2.7	19.8	16.3	5.5
Sample Size	9	75	13	89	4	3	193
Females							
Av. Length (mm)	0	515		573	518	589	565
Std Error	0	3.2		1.2	8.7	7.7	1.6
Sample Size	0	39		246	5	8	298
All Fish							
Av. Length (mm)	359	507	380	577	508	588	551
Std Error	3.8	3.1	5.6	1.2	10.2	6.7	2.5
Sample Size	9	114	13	336	9	11	492

Subsistence Harvest Estimate

The harvest census quantifying subsistence fishing effort and sockeye harvest at Eek Inlet was conducted from 15 June–31 August 2003. Hydaburg Cooperative Association (HCA) technicians conducted twenty-seven interviews with subsistence fishers returning from the Eek Inlet fishing grounds. The total harvest was 1,120 sockeye salmon, all participants in the fishery were interviewed, and the majority of fish were caught with seine nets (Table 7). The highest harvest for one day was 171 sockeye salmon on 30 July (Figure 4). Fifty percent of the total subsistence harvest was taken by 30 July (Appendix A).

Table 7.–Number of salmon harvested in the subsistence fishery at Eek Inlet, 2003, by gear and species. Harvest totals are based on interviews of 27 subsistence fishers (100% of participants) and are considered total counts, without sampling error.

Gear	Sockeye	Coho	Pink	Chum	Chinook
Gillnet	37	0	1	1	0
Seine	1,083	31	3	0	0
Total by species	1,120	31	4	1	0

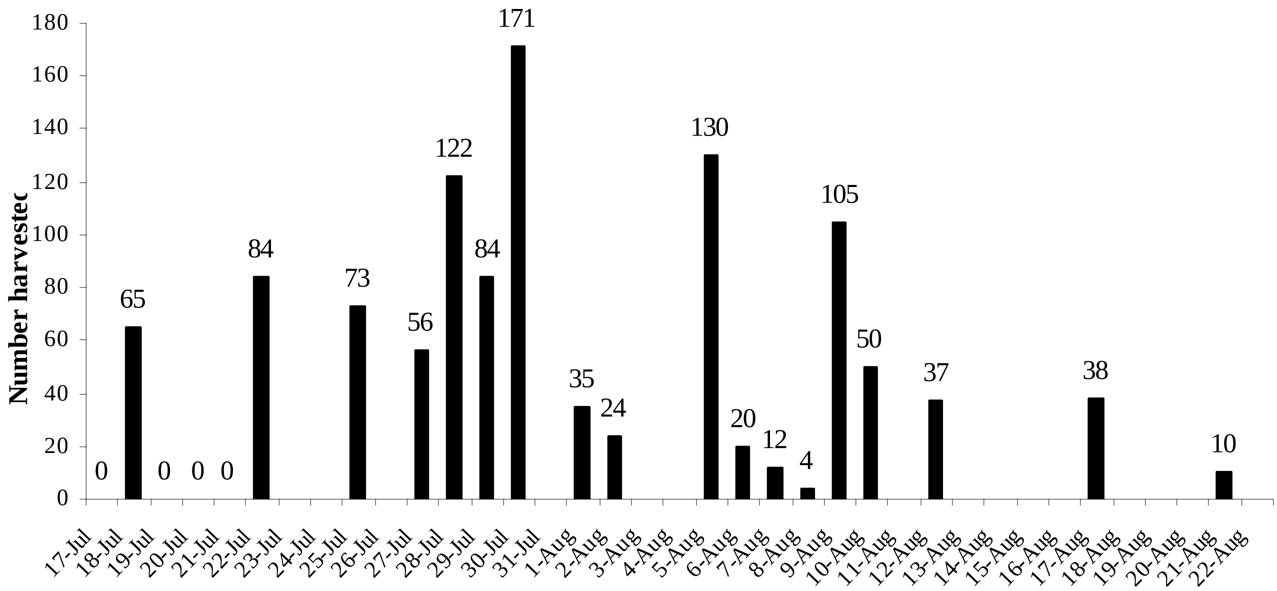


Figure 4.–The 2003 daily harvest of sockeye salmon in the Eek Inlet subsistence fishery reported by participants in interviews conducted on-site, at the docks, or in a call to the residence of the fisher.

LIMNOLOGY SAMPLING

Light, Temperature, and Dissolved Oxygen Profiles

Sampling occurred on 15 May, 26 June, 8 August, 10 September, and 14 October. The 2003 Eek Lake euphotic zone depth ranged from 3.0 to 5.1 m with a season mean of 4.4 m (Table 8). Temperature profiles showed weak stratification developing by 15 May and intensifying through 8 August. Temperatures were over 12^{o}C in the photosynthetic region of the lake in August. In September and October the lake was nearly isothermic (Figure 5). On 8 September, the water column was fully mixed at about 12^{o}C, a substantial increase in temperature in the lower depths. The percent oxygen saturation throughout the season varied by depth and sample date with the lowest levels of dissolved oxygen occurring in August (36%) close to the bottom (11 m; Table 9).

Table 8.–Euphotic zone depth (m) in Eek Lake, 2003.

Date	Euphotic Zone Depth (m)
15-May	5.1
26-Jun	4.5
8-Aug	5.0
10-Sep	3.0
14-Oct	4.3
Mean	4.4

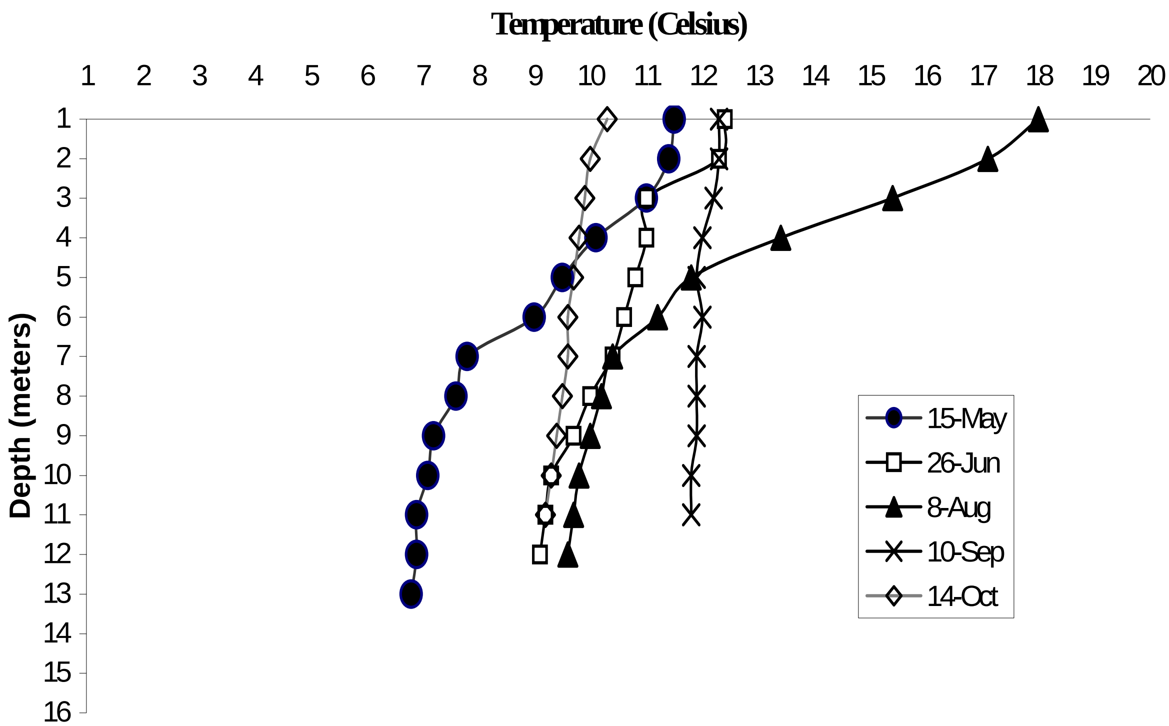


Figure 5.–Vertical profiles of the water temperatures by depth throughout the season in Eek Lake, 2003.

Table 9. –The 2003 percent oxygen saturation by depth and sample date in upper Eek Lake at Station A (13.5 m). The percent oxygen saturation was calculated by hand using a nomograph and the field measurements of dissolved oxygen (mg·L^{-1}) and temperatures (^{o}C) by depth (Koenings et al. 1987).

Depth (m)	15-May	26-Jun	8-Aug	10-Sep	14-Oct
1	92%	93%	94%	98%	93%
2	90%	92%	92%	87%	92%
3	90%	90%	86%	88%	90%
4	89%	89%	80%	87%	89%
5	87%	85%	69%	87%	88%
6	86%	85%	62%	89%	90%
7	84%	83%	56%	85%	90%
8	82%	76%	52%	82%	90%
9	80%	71%	46%	81%	90%
10	79%	58%	37%	80%	89%
11	73%	57%	36%	80%	

Secondary Production

Zooplankton species composition in Eek Lake was very simple, with only three taxa counted in the samples. The copepod *Cyclops* sp. dominated the zooplankton assemblage, comprising about 60% of total followed by *Bosmina* sp. (35%;Table 10;Appendix B). *Holopedium* was the only other taxon present in the samples. Species composition in terms of biomass was very similar, except that the proportion of *Holopedium* was slightly larger due to its larger body size (Table 11). The larger cladoceran, *Daphnia* sp., which is a preferred prey for sockeye fry, was not present in the samples.

Table 10. –Density of Eek Lake zooplankton in 2003, by taxon and sampling date. Seasonal mean is mean of values for all sampling dates; the species composition as percent of total numbers is also shown.

	Density (number of plankters per m^2) by date						
Species	**15-May**	**26-Jun**	**8-Aug**	**10-Sep**	**14-Oct**	**Seasonal Mean**	**% of Total Numbers**
Bosmina	26,000	67,200	78,600	12,000	3,500	37,000	34.1%
Ovig. *Bosmina*	400	0	3,900	200	200	1,000	0.8%
Cyclops	24,800	36,700	234,200	4,500	700	60,200	58.6%
Ovig. *Cyclops*	0	3,500	500	0	0	800	0.7%
Holopedium	6,500	5,000	3,900	1,800	0	3,000	3.5%
Ovig. *Holopedium*	1,500	1,100	1,500	200	0	800	0.8%
Copepod nauplii	7,100	0	0	0	300	1,500	1.7%
					Total seasonal mean density	105,000	

Table 11.– Seasonal mean length and biomass of Eek Lake zooplankton, 2003. Seasonal mean length and biomass are weighted by density; species composition as percent of total biomass is also shown.

Species	Season mean length (mm)	Season mean biomass ($mg \cdot m^{-2}$)	Percent of total biomass
Cyclops	0.62	73	57%
Ovig. *Cyclops*	0.91	3	2%
Bosmina	0.32	35	27%
Ovig. *Bosmina*	0.38	1	1%
Holopedium	0.52	12	9%
Ovig. *Holopedium*	0.73	5	4%
	Total seasonal mean biomass:	128	

DISCUSSION

We completed the 2003 objectives for the Eek Lake sockeye salmon stock assessment project including censusing the subsistence harvest on-site, estimating sockeye escapement with a coefficient of variation less than 15%, and collecting baseline limnological data. These results represent the first assessment of the Eek Lake sockeye spawning population.

The subsistence fishery harvested almost as many sockeye salmon as escaped into the lake, indicating there is considerable fishing pressure on the Eek Lake returns to the terminal area. The mixed-stock commercial fisheries in Hetta Inlet, some distance from the Eek Inlet, undoubtedly harvest Eek Lake sockeye salmon, but the actual numbers are unknown. The total commercial harvest of sockeye salmon in sub-district 103-25 has been small in the last few years; only about 110 fish were harvested in 2003. The sockeye harvest in 2000 was the highest in most recent years (about 2,800 fish).

The on-site harvest census indicates that there is gross under-reporting of subsistence harvest on the ADF&G subsistence permits. Only seven permit-holders submitted subsistence permits with sockeye harvests from Eek Inlet in 2003. The Eek Inlet sockeye harvest numbers (1,120 fish) obtained by interviewing fishers exceeded the total number reported on subsistence permits (153) by seven-fold. The difference between the reported catch and the interviews is due to the anonymity of the fishers in the interview system compared to the permit system. In other words, fishers are reluctant to submit their true harvest numbers on the subsistence permit in fear that they will be fined for exceeding the limit allowed on the permit (Tony Christensen, HCA Hetta Lake Project Manager, personal communication 2005). These on-site harvest interviews require very little effort and are critical in, not only getting an accurate harvest number, but also in understanding how the decision to fish a given system is made by the fishers. For example, in difficult economic times, Hydaburg residents will undoubtedly prefer to travel to the close by Eek or Hetta system compared to the more distant sockeye runs in Kasook and Hunter Bay. During subsistence harvest interviews in 2002 and 2003, the Hydaburg crew recorded sockeye salmon harvest totals for all three of the main subsistence sockeye fishing areas used by Hydaburg residents (Table 12). Hetta Lake is generally the largest producer of sockeye salmon, and in most years probably supplies the largest number of subsistence sockeye salmon to the people of Hydaburg, as it did in 2003 (Table 12). But in some years, as in 2002, when sockeye returns to the Hetta system were very low, Eek Lake may become the primary source of subsistence sockeye salmon for Hydaburg residents. In 2003, high fuel prices were also cited as a reason why people chose to fish in Eek Inlet rather than in Hetta Cove. Ideally, as we gain additional information about the Eek and Hetta sockeye populations and the potential bottlenecks to production, Hydaburg fishers will choose to fish in the most productive systems to ensure sustained runs in the more depressed systems.

Table 12. –Comparison of subsistence sockeye harvests at the Hetta, Eek, and Kasook terminal areas in 2002 and 2003. Harvest estimates were obtained from interviews of returning fishers in Hydaburg in 2002 and 2003.

Area fished	2002 harvest (percent of total)	2003 harvest (percent of total)
Hetta	947 (28%)	5,800 (78%)
Eek	1,200 (36%)	1,200 (16%)
Kasook	1,200 (36%)	450 (6%)
Total, all areas	3,347	7,450

Because Eek Lake is very shallow and small, the temperatures in the upper regions of the lake (12ºC) often exceeded the optimum temperature (10ºC) for sockeye salmon growth (Brett 1983). The 12ºC temperature throughout the water column in September may mean the sockeye fry could not escape to cooler water to minimize the metabolic costs associated with temperatures above their optimal range. Even during times when the lake was stratified, juvenile sockeye must spend a significant time feeding in the upper region of the lake. Furthermore, the percent of dissolved oxygen in the lower depths in August (36%) may be a major stressor to the sockeye juveniles in the warmest part of the season. This may be even more critical in years of dry and hot summers, which 2003 was not.

There appear to be no *Daphnia* in Eek Lake, or they were present at undetectable levels, leaving only the very small *Bosmina* and the larger but less numerous *Holopedium* as representatives of the cladoceran group. Furthermore, the rest of the zooplankton community appears to be simple—dominated by the copepod *Cyclops*. Given that sockeye fry prefer the slower and larger cladocerans (Koenings et al. 1987), the low level of cladocerans in this lake means that the fry must increase their handling time to consume small and less energetically valuable zooplankton species. In addition, the large cladocerans are more efficient grazers, fast-tracking the transfer of carbon up the food web (Mazumder and Edmondson 2002). The degree to which this hampers sockeye production is unknown. However the combination of the high temperatures, the lack of *Daphnia*, the fairly shallow euphotic zone depth (4.4 m), and low percent dissolved oxygen in August may naturally present enough stressors on these juvenile sockeye salmon to seriously limit production. Consequently, the exploitation rate of sockeye salmon may need to be lower than the current 50% in order for this population to be sustainable. Without more years of seasonal temperature information, and zooplankton and sockeye adult and fry population estimates, we cannot say whether the food resources in Eek Lake are sufficient to support the offspring of the current or larger escapements. The fact that over 90% of the 2003 escapement were fish with one freshwater year (age-1.2 and –1.3) suggests that the lake was not food limited during the years they were rearing in the lake (1999 and 2000; Koenings and Burkett 1987). Therefore, we recommend continued sampling of the zooplankton and lake temperatures as well as the sockeye spawning population in Eek Lake. We also recommend performing a hydroacoustic survey in the upper and lower lakes to determine the extent that sockeye fry use these lakes. Even if Eek Lake is not food limited, we don't know whether the spawning area in Eek Lake is sufficient to produce larger numbers of fry from larger escapements. The acoustic estimates of sockeye fry populations would also assist in answering this question especially the year after a high return of adults. The morphology of the lake may limit sockeye production as mentioned earlier, especially in hot dry summers. The only other clue we have at this time to potential productivity of the Eek Lake system is in historical records showing harvests of 1,000–9,000 sockeye salmon in or near the terminal area during early commercial exploitation in the late 1800s and early 1900s—placing the 2003 escapement estimate at the lower end of this historical range. Results of the 2003 study indicate a need for continued monitoring of both harvest and escapements into Eek Lake, in conjunction with the ongoing study at Hetta Lake.

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APPENDICES

Appendix A.–Subsistence harvest census data for Eek Inlet, 2003. Although the subsistence season began on 17 June, no fishing effort occurred until 18 July.

Date	Interview no.	Interview type H=harbor G= grounds	Time (military)	Gear type S=seine GN= gillnet	Hours fished	No. of Sets	Sockeye	Coho	Chum	Chinook	Pink	CPUE	Cumulative	Other
6/17–7/17							0						0	no activity
7/18	1	H	1800	S	3.5	3	65						65	first set and first fish
7/19							0						65	no activity
7/20							0						65	no activity
7/21							0						65	no activity
7/22	1	H	1900	S	1.5	2	60						125	
7/22	2	H	1530	S	2	1	24				1		149	
7/23							0						149	no activity
7/24							0						149	no activity
7/25	1	G	2000	S	5	4	73						222	
7/26							0						222	no activity
7/27	1	H	1300	S	5	2	13						235	
7/27	2	H	1800	GN	3	1	25		1				260	
7/27	3	H	1500	S	4.5	8	9	4			2		269	
7/27	4	H	1330	GN	5	1	9				1		278	
7/28	1	G	1800	S	5	5	102	4					380	
7/28	2	G	1300	S	5	2	20	2					400	
7/29	1	H	1200	S	2	1	81	4					481	
7/29	2	H	1500	GN	3.5	1	3						484	
7/30	1	H	1340	S	4	5	92						576	
7/30	2	G	2000	S	4	2	40						616	
7/30	3	G	2000	S	3	3	39						655	
7/31							0						655	no activity
8/1	1	H	1430	S	6	3	35						690	
8/2	1	H	2100	S	2	1	24						714	
8/3							0						714	no activity
8/4							0						714	no activity
8/5	1	G	1800	S	4	4	130						844	
8/6	1	H	1730	S	3	2	20						864	few sockeye lots of pinks
8/7	1	G	1200	S	3	3	12						876	
8/8	1	G	1100	S	1		4						880	
8/9	1	G	1930	S	6	6	60						940	
8/9	2	G	1930	S	6	7	45						985	
8/10	1	G	2100	S	7	7	50						1035	
8/11							0						1035	
8/12	1	G	2030	S	2	4	37	4					1072	lots of pinks
8/13							0						1072	no activity
8/14							0						1072	no activity
8/15							0						1072	no activity

-continued-

Appendix A.–Page 2 of 2.

Date	Interview no.	type H=harbor G=	Time (military)	Gear type S=seine GN= gillnet	Hours fished	No. of Sets	Sockeye	Coho	Chum	Chinook	Pink	CPUE	Cumulative	Other
8/16							0						1072	no activity
8/17	1	G	2030	S	3	3	38	12					1110	lots of coho
8/18							0						1110	no activity
8/19							0						1110	no activity
8/20							0						1110	no activity
8/21	1			S	1	1	10	1					1120	
8/22							0						1120	no activity
8/23							0						1120	no activity
8/24							0						1120	no activity
8/25							0						1120	no activity
8/26							0						1120	no activity
8/27							0						1120	no activity
8/28							0						1120	no activity
8/29							0						1120	no activity
8/30							0						1120	no activity
8/31							0						1120	no activity
Totals	27				100.0	82	1120					11.20		

Appendix B.–The 2003 estimated density of zooplankton (number per m^2) in Eek Lake by species, by station, and an average between both stations for each sample date. The mean seasonal zooplankton estimate and percent of the total zooplankton for each species was calculated by species, station and averaged across both stations and the 5 sample dates.

Station A	**15-May**	**26-Jun**	**8-Aug**	**10-Sep**	**14-Oct**	**Season mean**	**Percent of total**
Bosmina	21,396	107,998	117,168	21,905	3,923	54,478	38.7%
Ovigerous Bosmina	408	0	6,792	306	306	1,562	1.1%
Cyclops	16,234	60,112	300,985	7,234	713	77,056	54.7%
Ovigerous Cyclops	0	6,368	425	0	0	1,358	1.0%
Holopedium	4,211	7,132	6,792	2,038	0	4,035	2.9%
Ovigerous Holopedium	1,019	1,783	2,972	102	0	1,175	0.8%
Copepod nauplii	5,841	0	0	0	272	1,223	0.9%
Total	132,654	227,067	645,016	37,137	9,051	140,886	
Station B							
Bosmina	30,565	26,354	39,990	2,038	3,158	20,421	29.4%
Ovigerous Bosmina	408	0	1,019	51	68	309	0.4%
Cyclops	33,418	13,381	167,346	1,681	611	43,287	62.4%
Ovigerous Cyclops	0	679	509	0	0	238	0.3%
Holopedium	8,762	2,921	1,019	1,579	0	2,856	4.1%
Ovigerous Holopedium	2,038	340	0	204	0	516	0.7%
Copepod nauplii	8,355	0	0	0	272	1,725	2.5%
Total	83,546	43,675	209,883	5,553	4,109	69,353	
Average, both stations							
Bosmina	25,981	67,176	78,579	11,971	3,540	37,449	34.1%
Ovigerous Bosmina	408	0	3,906	178	187	936	0.8%
Cyclops	24,826	36,746	234,165	4,457	662	60,172	58.6%
Ovigerous Cyclops	0	3,524	467	0	0	798	0.7%
Holopedium	6,487	5,026	3,906	1,808	0	3,445	3.5%
Ovigerous Holopedium	1,528	1,061	1,486	153	0	846	0.8%
Copepod nauplii	7,098	0	0	0	272	1,474	1.7%
Total	108,100	135,371	427,449	21,345	6,580	105,120	